

CYCLE TIME OPTIMIZED PATH PLANNING FOR INDUSTRIAL ROBOT USING ROBOMASTER

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ABSTRACT

The main aim of the paper is to demonstrate the optimal cycle time taken by a 6 axis industrial robot, by following the shortest path. Planning for path is important because, it allows knowing about the path traversal of robot from starting point and reaching the end point with shortest possible time in 3D workspace. The approach of this work is based on the use of robomaster software, for solving the path planning problems for industrial robot arms, that are used in industries and for any dynamic environments. In this analysis, an attempt has been taken to plan the path followed by the robot, by considering different sort options with different starting points. The analysis of different paths with cycle time and path length are done and from that, one having the shortest cycle time and minimum path length is achieved, which can be considered for further machining works.

KEYWORDS: Cycle Time, Industrial Robot, Path Planning, Robomaster and Workspace

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INTRODUCTION

The performance of industrial robot is more important by considering their movement with high speeds, short time and with large accelerations. The use of robot in production sector depends upon the efficiency with which it performs a given task with shortest possible time, which in turn predicts the production rates. The highest priority given to the optimisation criterion is, the robot cycle times considering the limits of robot such as, maximum motor speeds and robot arm design etc. Also energy consumptions of the motors can be used as additional lower priority criteria, which are not considered for our work. Therefore, a good specification of robot is essential to get economically sound performance.

Carlason et al. [1] worked on dimensional quality and cycle time, based on search algorithm and proposed a novel method for optimization. Ulrich et al. [2] improved the flexibility of inspection system, based on robots by generating an automated path planning algorithm, which gives collision free path and optimised the time. Abele et al. [3] generated the time optimal tool paths, for a robot based deburring process of internal contours, by Matlab interface to find the shortest path by solving the travelling salesman problem. Gigras et al. [4] presented a new ant colony based approach, which is helpful in solving path planning problem for autonomous robotic application. Willigenburg et al. [5] used kinematic path planner, to find the minimum time taken for the path planning and proposed a new computational method. Cristina Castejon et al. [6] proposed the design criteria using computationally efficient objective function and investigated the main characteristic of service tasks. Saravanan et al. [7] proposed a method to find out optimal motion of a robot arm, in the presence of a fixed as well as oscillating obstacles, in the path of robot structure. Rahman et al. [8] proposed a framework for determining workspace of industrial robot, for providing a fast and easy configuration approach, for safe robot working area

using CAD software. Ting et al. [9] improved the accuracy and efficiency of robot, in the presence of obstacles and developed an algorithm for path planning of robots, used in industries.

DESIGN ANALYSIS

Describing Robot Workspace

Workspace of robot is the set of points that can be reached by robot end-effectors. For application of robot in industries or in any work environment, the workspace is very important to analyse. Evaluation of robot workspace is important to optimise the design process and for this, three things should be taken into consideration such as, the maximum reach of the robot, position workspace volume and orientation workspace volume. The 6 axis industrial robot and its workspace are shown below, in figure 1 and figure 2, respectively.

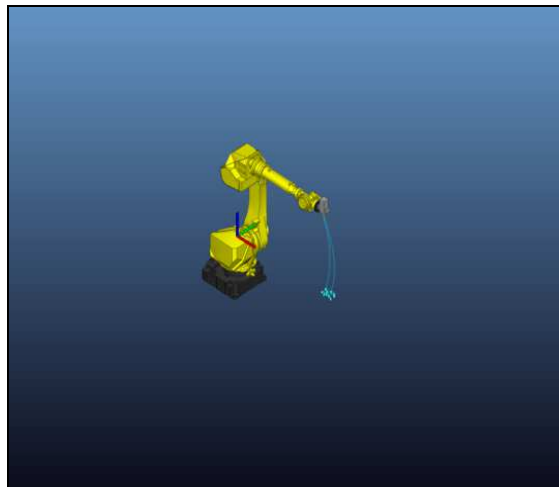


Figure 1: 6 Axis Industrial Robot

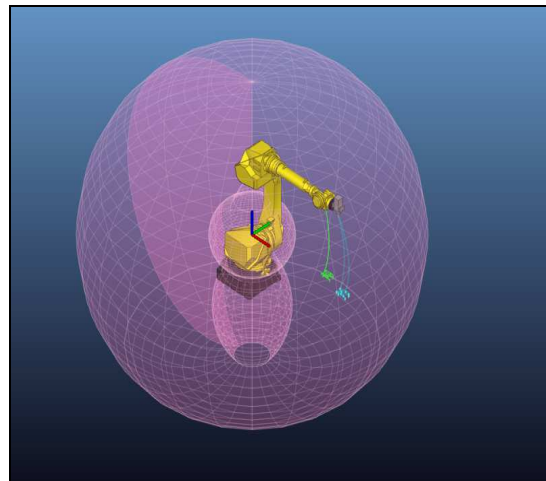


Figure 2: Workspace of Robot

Path Planning of Industrial Robot

For the design optimisation of robot, the layout of path has the major influence. The path with shortest path distance is considered as optimal path, as long as cycle time is concerned. Therefore, it is necessary to have idea about the paths followed by the robot and choose the path which can be useful, to optimise the design process. In this case, the optimisation criterion taken is the cycle time. For the analysis of cycle time taken by the industrial robot, ten numbers of

tasks has been given, which is shown in below figure 2 and these are given the numbers, from 1 to 10.

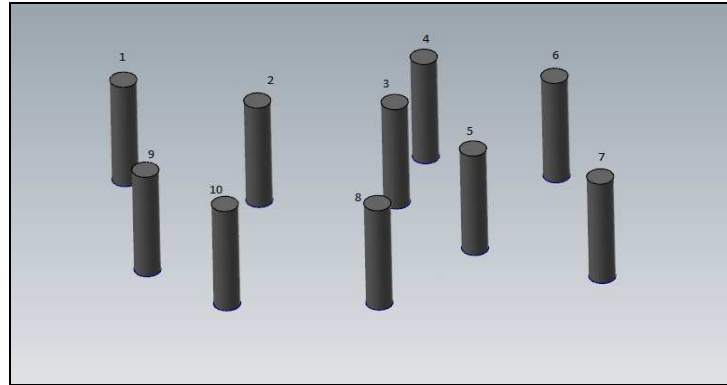


Figure 3: Arrangement of Tasks

For this particular analysis, a drilling tool is used which is replacing the gripper of the industrial robot. The light blue line in the figure 3 shows the movement of the tool from home position, passing through all the tasks and returning back to its home position.

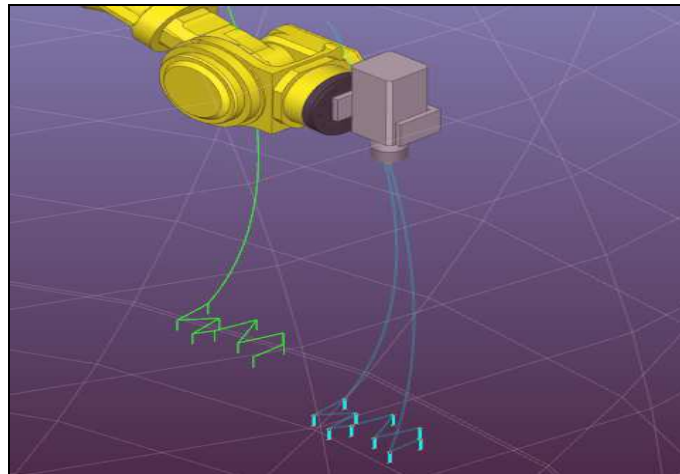


Figure 4: Robot Performance with in the Workspace

The six axis industrial robot consists of base, shoulder, elbow, wrist, pitch and roll. The base can revolve from 90° to 250° . It is the supporting lowest part of the robot. The shoulder can move between -45° & -90° for forward and backward motion of robot. During picking of the object, the elbow can play between 45° & 115° , for up and down movement. Wrist can play between 0° to 340° . Pitch can move an angle between -90° to 90° and roll can revolve between 0° to 340° . Wrist, Pitch and roll, all make the robot flexible enough for picking and placing objects. Below Figure5, shows the movements of the six axes in X, Y & Z coordinates.

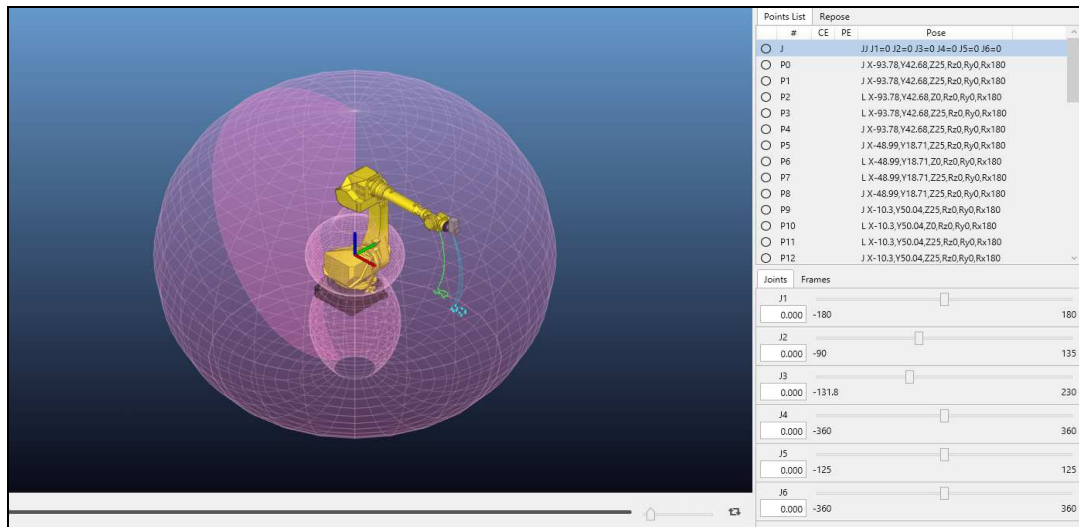
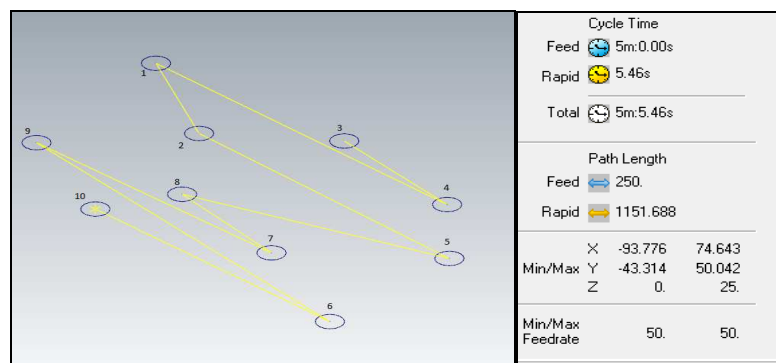


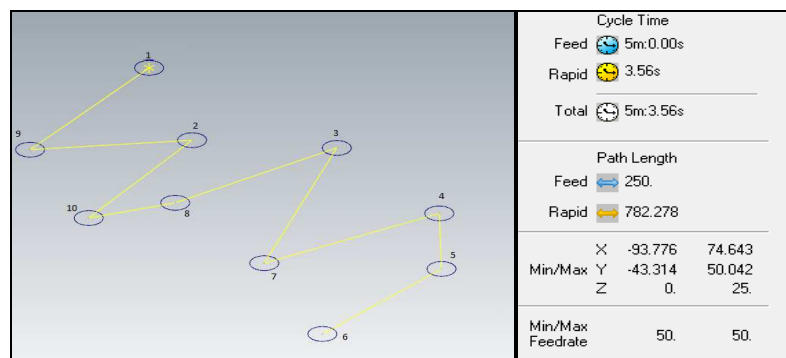
Figure 5: Movements of Six Joints in X, Y & Z Coordinates

RESULTS

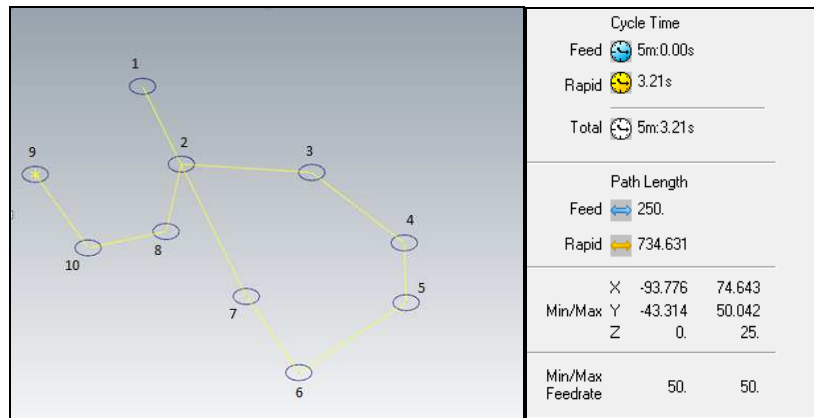
In order to analyze the performance of the robot, simulations were run several times, to obtain best value of cycle time. After analysing different paths followed by the robot to pass through ten tasks given, only seven paths have been selected, comparing with the path length and cycle time of each path. The Figure 5 shows the seven different paths followed by robot, to go through ten tasks. The left side figure shows the path and right side figure shows the cycle time, taken by the robot to follow that particular path, along with its path length. These figures are obtained from robomaster, by selecting different sort options for path planning of robot.



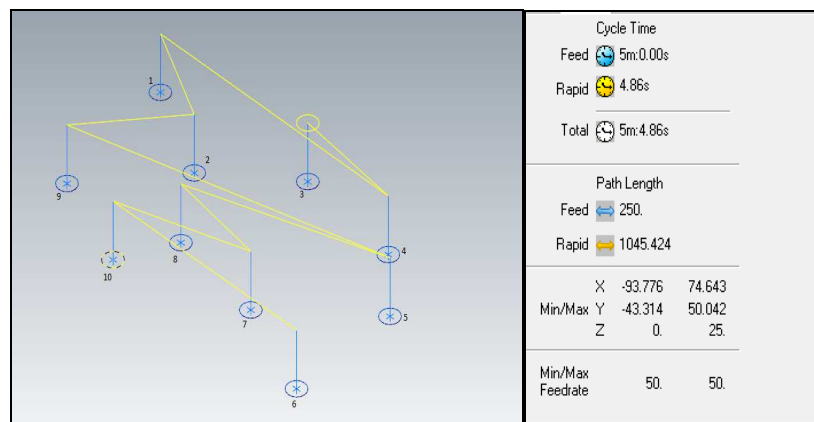
Path 1



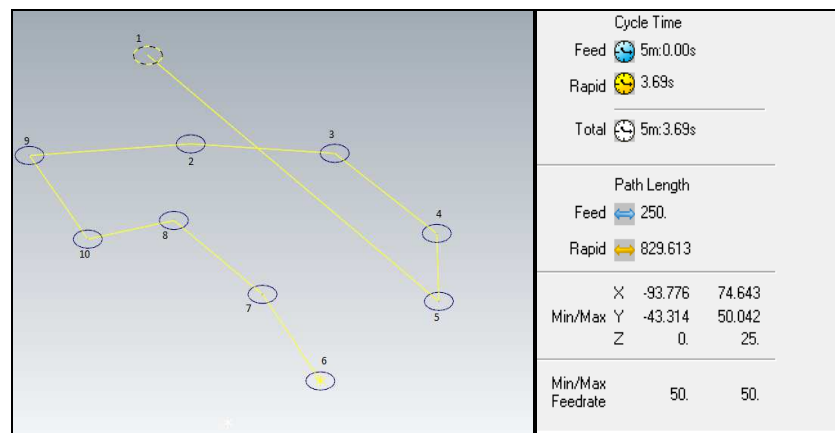
Path 2



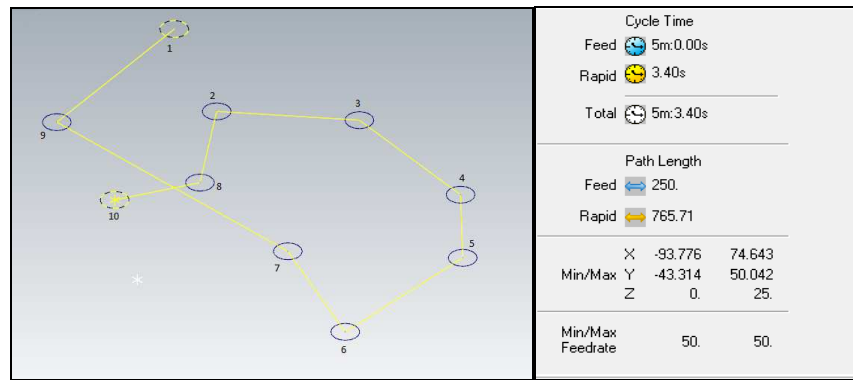
Path 3



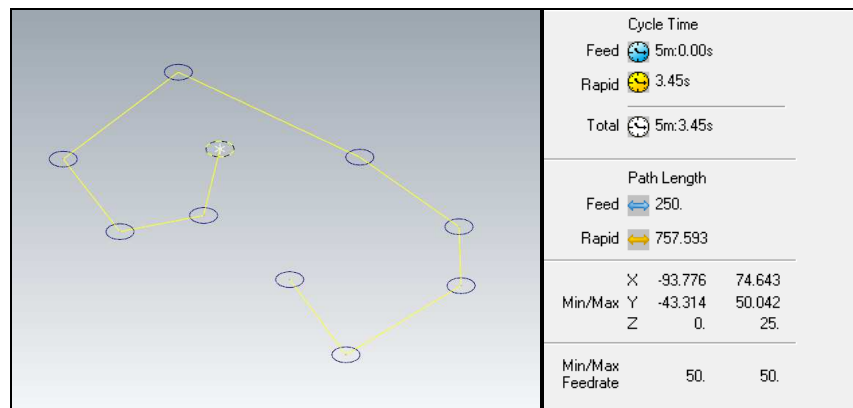
Path 4



Path 5



Path 6



Path 7

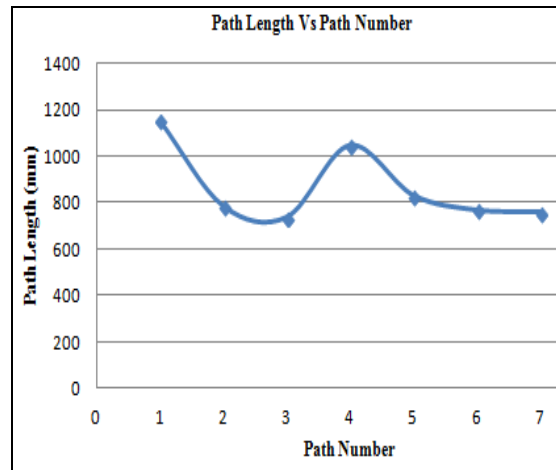
Figure 5: Paths Followed by Robot for the Given Task

The Path Length and Cycle Time for seven different paths as discussed are presented in table 1. It is seen from the table that, for path number 1 the cycle time taken is 5.46 second, which is the highest value observed, corresponding to the path length of 1151.688 mm. Whereas, for path number 3 the path length is 734.631 mm, which is the lowest path length and cycle time taken is 3.21 second, which is the optimal cycle time period, taken by the robot to follow that path.

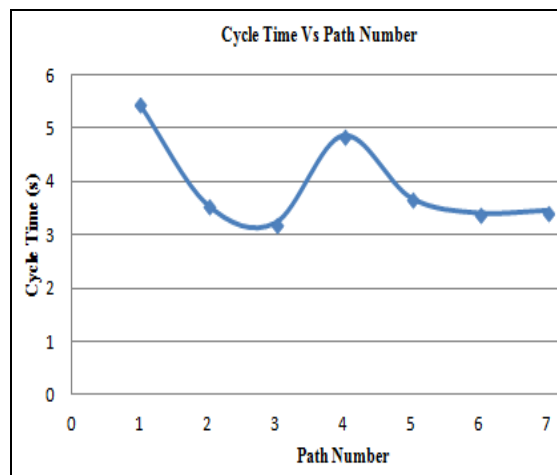
Table 1: Path Length and Cycle Time for Seven Different Paths

S No	Paths	Path Length (mm)	Cycle Time (second)
1	Path1	1151.688	5.46
2	Path2	782.278	3.56
3	Path3	734.631	3.21
4	Path4	1045.424	4.86
5	Path5	829.613	3.69
6	Path6	765.71	3.40
7	Path7	757.593	3.45

The results from the simulation are presented below, in Figure 6 in the form of graphs. These two graphs (a and b) are nearly similar, because as path length increases, cycle time increases. It is seen from both the graphs that, for the path number 3 the lowest path length and the optimum cycle time is achieved.



(a)



(b)

Figure 6: Comparison of Path Length (a) and Cycle Time (b) for Seven Different Paths

CONCLUSIONS

In this work, we evaluated and demonstrated the path planning method, in conjunction with shortest path traversal of the 6 axis industrial robot. Therefore, this paper proposes a solution for path planning, by obtaining the optimal cycle time with shortest path, followed using mastecam and robomaster software. Considering the workspace with its limit of working range, this method may be proposed for selection of tool path during machining with robot in industries or in any working environment. This proposed method may also be used for design optimisation of robots, to increase the flexibility and to make the robot more efficient and economic for future work.

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